A MEASURING SETUP FOR THE CHARACTERISATION OF 'IN-CIRCUIT' CONDUCTIVE GASKETS UP TO 40 GHz

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Abstract: Due to the impact of higher and higher frequencies, the Shielding Effectiveness (SE) characterisation of shielding gaskets at frequencies above 1 GHz is needed for the so called 'in-cicuit' and 'on board' shielding applications. In this paper, the frequency range of an earlier proposed stripline method is expanded up to 40 GHz.

Keywords: conductive gaskets, shielding

1. INTRODUCTION

Due to the impact of higher and higher frequencies, the SE characterisation of shielding gaskets at frequencies above 1 GHz is needed for in-circuit and on board shielding applications. These types of shielding are applications where noisy components must be shielded, in order to cause no interference with the environment (intersystem EMC) or with adjacent electronic components (intrasystem EMC). It must be noted that wireless communication systems are not only moving into very high frequencies, but are operated at low transmitted power, requiring a very clean and low noise floor for errorless reception.
The quality of shielding strongly depends on the way conductive contact is made from the small enclosure (CAN) to the ground plane of the PCB, or in between compartments of enclosures with separate parts.

In the standard IEEE Std 1302™ - 2008 [1] is Annex E dealing with this topic in a short and only informative way. The problem is shown in figure 1.

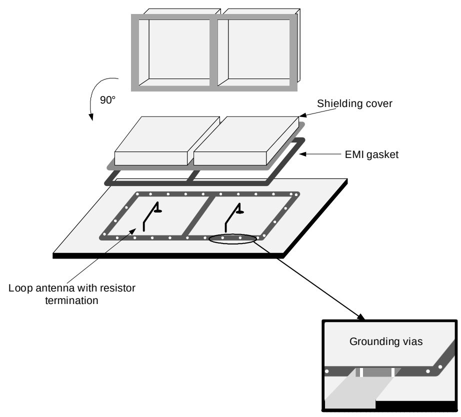


Figure 1. Typical configuration of on board shielding

It is clear that appropriate measuring methods are needed to characterise shielding gaskets for these specific applications.

In an earlier papers [2]–[3], a method was proposed for the frequency range up to 18 GHz. In this paper, the method is proved to be expanded up to 40 GHz.

2. NOVEL MEASURING METHOD FOR IC's

In order to overcome some of the disadvantages identified when using standardised test methods, another setup has been developed [2]-[3].
Recently, an interesting test methodology has been proposed for susceptibility and emission testing of IC's: IC stripline method [5]-[7]. The method is based on putting a stripline over a PCB board with a full GND layer, so that susceptibility or emission of an Integrated Circuit may be performed. The principle of the setup is sketched in figure 2.

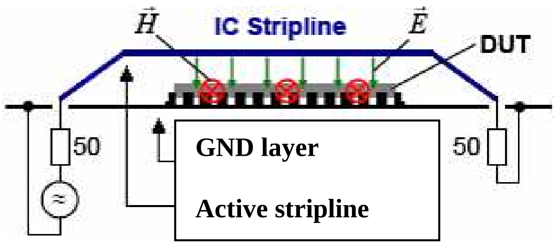


Figure 2. Principle setup of the proposed stripline method in order to characterize IC's

For the frequency range concerned, the question is how substitute the IC under test by a well defined source/victim, in order to have a setup independent from the type of IC or the like.

3. CHOICE OF TYPE OF SOURCE/VICTIM

For the frequency range concerned, it is still supposed that the dominant coupling path is generated by the traces on a PCB and the pinning/bonding wires of the chip package.
Therefore, a substitute for the traces belonging to the circuitry to be shielded has been chosen.
The most simple substitute is the use of a microstrip (µstrip) simulating just a trace on the PCB's. The advantage is that a 50 Ohm µstrip can be designed and terminated into a 50 Ohm load.

As an alternative, a kind of printed loop could be used, simulating a more complex set of PCB traces. Numerical simulations for both configurations has been performed using the Agilent EMPro [8].

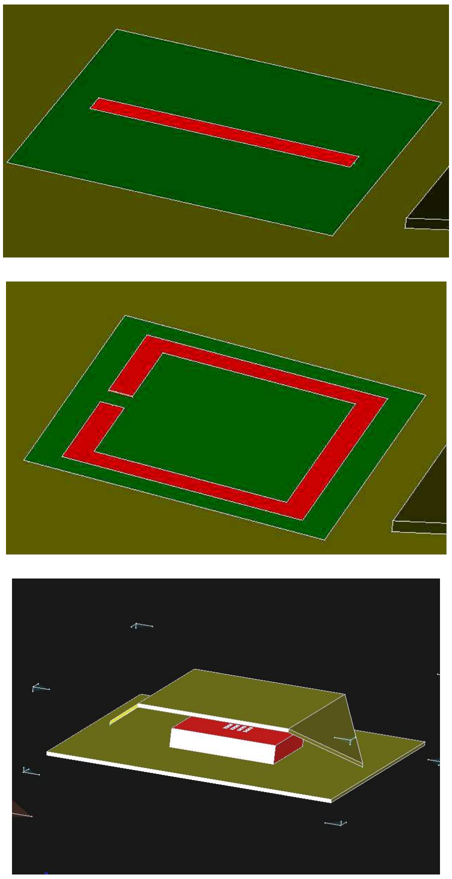


Figure 3. µstrip, loop and full setup as used for the numerical simulations

By replacing the IC under test by one of the substitute circuits embedded in a thick ground plate, and using another plate to clamp and compress a gasket to the chassis of the system, a matched measuring setup is obtained, with a direct relationship to the physical and mechanical environment of on-board shielding.

The proposed measuring setup is shown in the next figures 4 - 6 and has an overall size of 17x20 cm.
In this paper, only the realization with a µstrip as substitute has been taken into account and is shown in the figures 6. See also section 4 o f this paper.

A stripline has been designed to fit a characteristic impedance of 50 Ohm (red arrow). The width of the stripline is 12 cm and the height above the solid GND copper plate is 2.6 cm. The active length of the stripline is 9 cm, and both tapering sections are 3 cm each.

The inner side of the stripline is covered with an absorbing ferrite sheet, to avoid too much influence of the short tapering. SMA connectors are mounted through the solid GND plate.

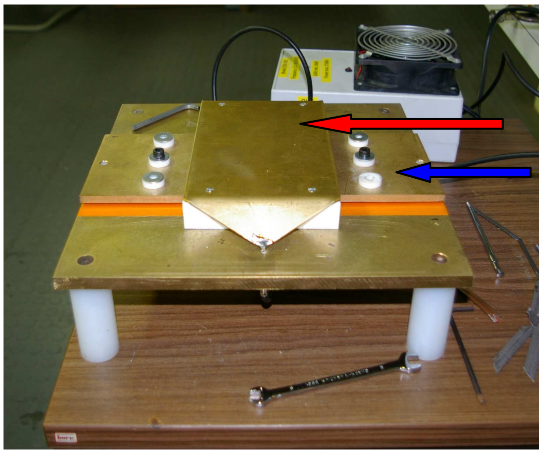


Figure 4. Overall view of the stripline setup

Another solid copper plate is intended to hold the gasket, and is inserted in the open area of the stripline (blue arrow).

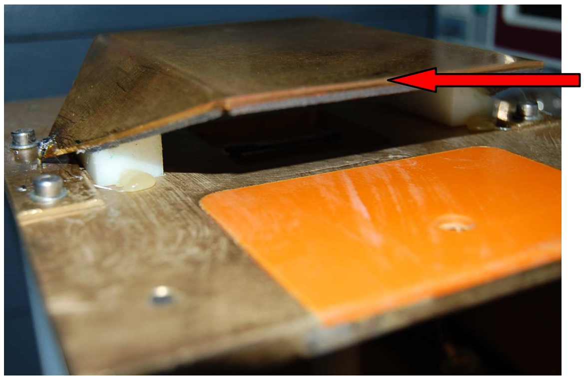


Figure 5. Detailed view of the stripline setup

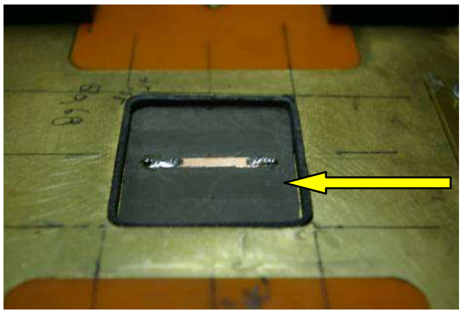


Figure 6. General view of base-plate and embedded µstrip

The µstrip is embedded in the GND plate and surrounded by absorbing material, as can be seen in figure 6.
Both µstrip and stripline are terminated in a 50 Ohm resistive load at one end. The other ends are the transmitter and receiver part of the set up.

4. NUMERICAL SIMULATIONS

The next figures show the simulated S parameters of the system, where S23 is the fext coupling between the µstrip and the stripline and S13 is the next coupling, following the wording used for directional couplers.

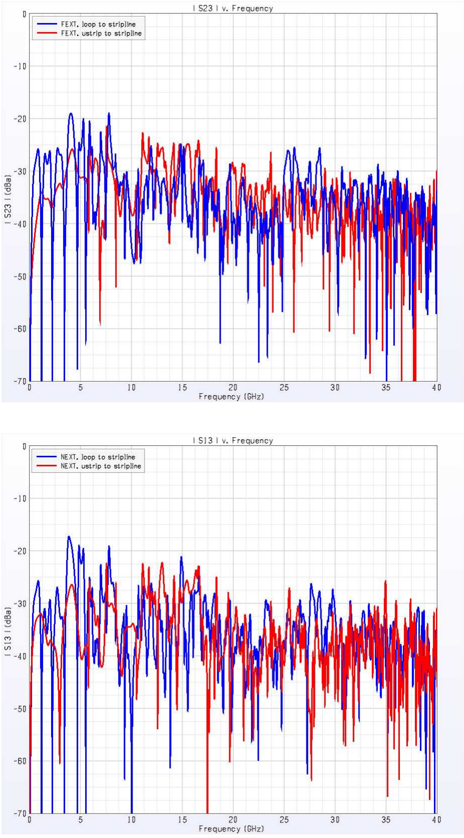
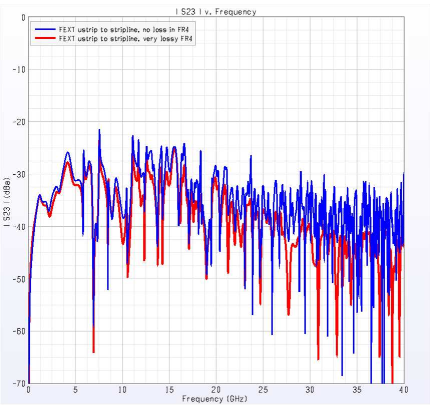


Figure 7. Coupling between µstrip (red) or loop (blue) and stripline for FEXT (upper) and NEXT (lower)

As there is no apparent difference between both configurations, it was decided that only the most simple one, in this case the µstrip configuration, should be realized and constructed in practice.
Consequently, only for the µstrip configuration, the influence of losses in the µstrip substrate has been evaluated, as shown in the next figures.
The blue lines are the coupling parameter without losses, and the red lines are with losses taken into account.

No clear differences between FEXT and NEXT coupling are identified, so that there is also no preference in the practical use of the set up. Therefore, only the



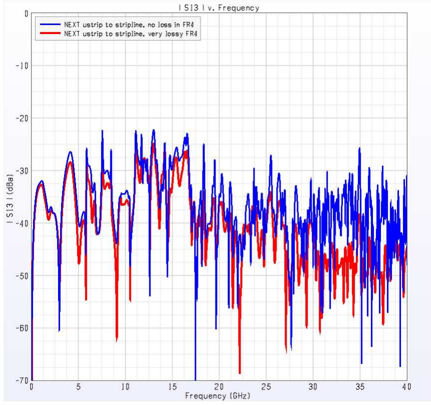


Figure 8. Coupling for µstrip without losses (blue) or µstrip with losses (red) for FEXT (upper) and NEXT (lower)

It can be concluded that a good choice of the substrate will highly enhance the coupling between both parts, and consequently enhance the dynamic range of the set up.

5. PRACTICAL REALIZATION

A stripline has been designed to fit a characteristic impedance of 50 Ohm (red arrow in figure 4). The width of the stripline is 12 cm and the height above the solid GND copper plate is 2.6 cm. The active length of the stripline is 9 cm, and both tapering sections are 3 cm each.
The inner side of the stripline is covered with an absorbing ferrite sheet, to avoid too much influence of the short tapering. SMA connectors are mounted through the solid GND plate.

Embedded in the solid GND plate, there is a small 50 Ohm µstrip (figure 6), with a matched load of 50 Ohm connected via an SMA connector through the GND plate.
The µstrip has a length of 4 cm and is made on an appropriate substrate of microwave PCB material, and is embedded in a 5x5 cm opening. It is surrounded on the vertical "walls" by an absorbing material, in order to reduce the resonant effects of this "virtual" embedded enclosure.

By covering this embedded µstrip with a plate or sheet (blue arrow in figure 4), the Shielding Effectiveness (SE) of this material can be evaluated, by performing two measurements: a first one as the coupling between µstrip and stripline in an open structure and a second one with the sample.

Using a solid copper plate to cover the embedded µstrip, and inserting a gasket in between this plate and the solid GND plate of the stripline structure, the SE of the gasket can be measured.
In this way, the copper plate can act as a gasket sample holder, and the gasket may be carefully positioned on this solid plate. This is shown in figure 9. When placing this sample holder in place, the embedded µstrip is exactly within the inner surface area limited by the gasket.

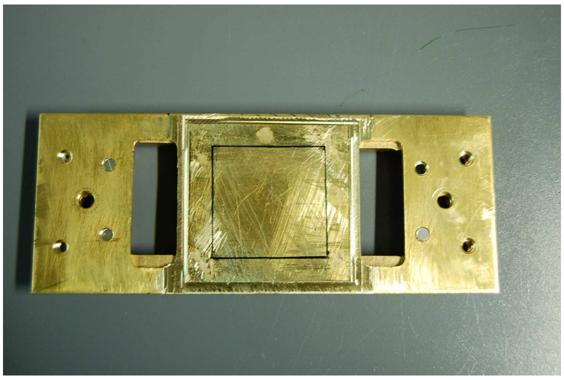


Figure 9. Solid copper plate acting as gasket sample holder

6. FIRST VALIDATION (14 GHz)

Due to the availability of measuring equipment, a preliminary validation of the system was performed up to the frequency of 14 GHz.
For the purpose of this paper, a set of 3 gaskets has been used, by courtesy of SEM.
For this purpose, the noise floor of the VNA was minimised by controlling the measuring BW down to 100 Hz. Care was also taken to use low loss cables and to ensure a very good shielded connection from the setup to the VNA, minimising CM noise pickup by the measuring setup.
The dynamic range was increased by inserting a broadband amplifier of 20 dB gain between the output of the VNA and the test setup.

Some of these effects are clearly shown in the next figure 10: the influence of a low impedance GND connection to CM noise pick up (lower red curve <> lower blue curve) and the effect on the dynamic range of the 20 dB amplifier (upper curves).

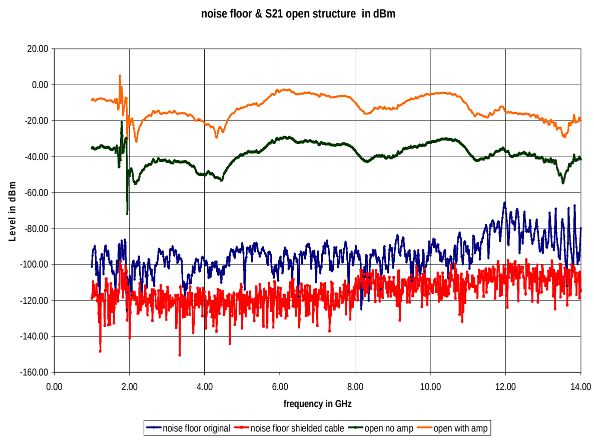


Figure 10. Noise floor and injected signal levels

For a first set of tests, three different gaskets have been used. They have all the same shape, but differ from the wrapping material around the compressible foam. The next figure 11 shows a typical gasket used for these tests, which is fold into a square to fit onto the clamping plate.

Figure 11. Example of a typical gasket used in this study

The gaskets have been compressed onto a remaining thickness of 1.5 mm, which consists of a compression rate of about 50%.

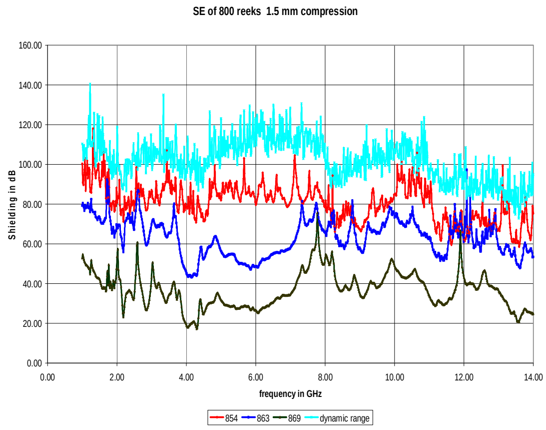


Figure 12. SE values of three different gaskets and DR

The resulting SE values are shown in the figure 12 above. The upper curve shows the resulting dynamic range (DR) of the system. The DR is obtained by clamping a reference gasket down to nearly 100% compression, so that the clamping plate and the base plate are "completely" closed.
Under the conditions of the low noise floor, the use of a 20 dB amplifier and a careful setup, a DR of around 100 dB is obtained.
The other three graphs represent the measured SE of the gaskets. It is clear that a good discrimination between the different wrapping around materials is observed and can be evaluated.

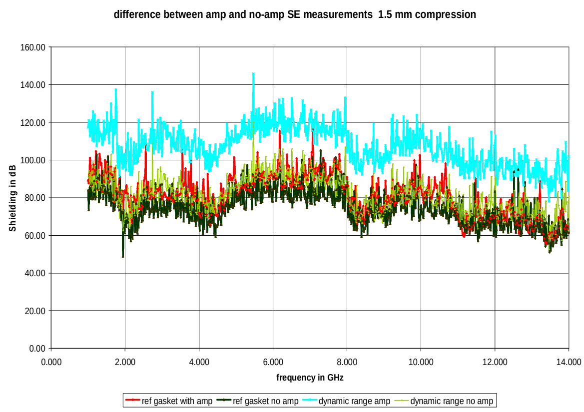


Figure 13. Influence of DR on measured SE value

The importance of a high DR value is shown in figure 13. It shows the DR obtained without and with a 20 dB amplifier. This results in a SE value identical to the DR, when no amplifier is used. This means that in fact, the real SE can not be estimated. When an amplifier is used to increase the DR, the SE value is correctly taken from the measurements.

7. PRELIMINARY VALIDATION: 40 GHz

At the research lab MICAS/ESAT/KULeuven, a combined system of a generator (Agilent type E8257D PSG analog signal generator) and a spectrum analyser (Rhode&Schwarz type FSU 40) is recently becoming available for these measurements. However, the equipment is not yet fully integrated in the automated measuring system of the lab. This will be realised in the first quarter of 2012. Only some measurements performed in a manual way were possible, at the following spot frequencies: 20, 25, 30, 35 and 40 GHz. ***Full measurements will be reported in the final paper.*** Unfortunately, at the moment of these tests, no amplifier up to this frequency was available. Measurements were performed at a signal level of 10 dBm output of the generator, and consequently only a reduced DR was available.

In the past, intermediate validation measurements have been performed up to a frequency of 20 GHz. These measurements were done by using a VNA and optimising the BW for low noise, but without amplifier. The measuring conditions are similar to the recent ones up to 40 GHz and will be combined in the next figures.
The labelling is as follows:

- VNA with high noise floor/40 GHz – no extra amplifier (blue line)
- VNA with low noise floor/20 GHz) and combined with similar measurements up to 40 GHz (MICAS) – no extra amplifier (dark green line)
- VNA with low noise floor/14 GHz and with an extra 20 dB gain amplifier - FMEC (red line)

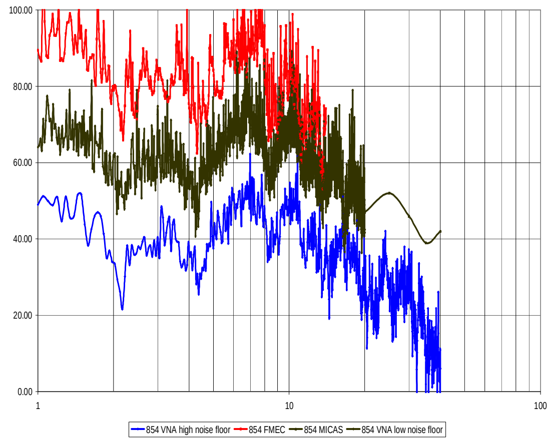


Figure 16a. Comparison of the different measuring set ups for the different gaskets under test

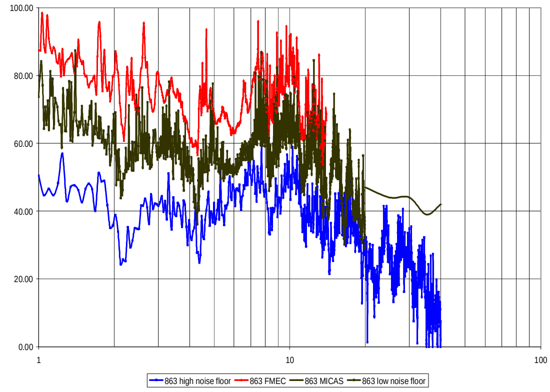


Figure 16b. Comparison of the different measuring set ups for the different gaskets under test

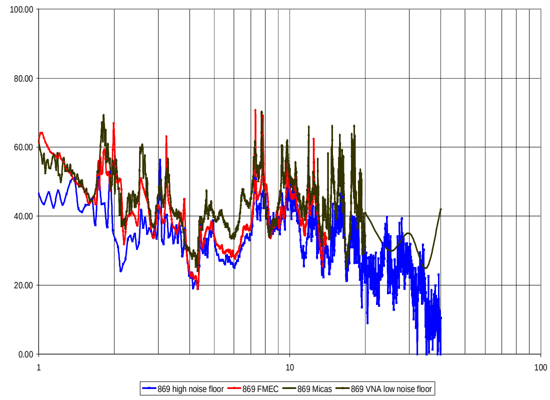


Figure 16c. Comparison of the different measuring set ups for the different gaskets under test

From all figures, but especially from figures 16a and 16b, the importance of a high DR range is clearly observed. All SE values are hidden by the DR of the appropriate system, and the influence of both a low noise floor and an extra amplifier are identified.

When the SE value is lower than the DR, a correct measurement is obtained, which is repeatable over different measuring setups. This can be seen in figure 16c, where still the high noise floor setup (blue line) is still hiding the real SE value.

CONCLUSIONS

A novel compact and easy to handle test fixture for the characterization of on-board PCB shielding gaskets up to a frequency of 40 GHz, has been discussed and validated.

The proposed measuring setup shows clearly the effects of low conductive contacting of a gasket, and offers a very valuable engineering tool, in order to get SE values that can directly applied when designing on-board shielding enclosures at PCB level and taking into account the stripline EMC characterization of IC's [3] – [5].

The dominant influence of both the noise floor of the receiver and the output signal level of the generator, as well as the effects of lossy measuring cables, have been identified. The use of an extra amplifier and very low loss cables is suggested and even recommended to enhance the available Dynamic Range (DR) of the system.
It can be stated that a DR of more than 80 dB can be achieved over the whole frequency range from 1 up to 40 GHz.

References

[1] IEEE Std 1302™ – 2008, "IEEE Guide for the Electromagnetic Characterization of Conductive Gaskets in the Frequency Range of DC to 18 GHz", IEEE, nov. 2008

[2] J. Catrysse et al., "A New Stipline Measuring Setup for the Characterisation of conductive gaskets up to 18 GHz", Proceedings IEEE EMC International Symposium 2010

[3] J. Catrysse et al, "Towards a global approach for the characterization of IC's and on board shielding components", Proceedings EMC Europe 2010, Wroclaw, September 2010

[4] F. Vanhee, B. Vanhee, J.Catrysse, "Proposed methods to measure the shielding performance of PCB level enclosures", Proc. Int. Symp.on EMC, Kyoto, July 2009

[5] B. Koerber et al., "IC-stripline: a new proposal for susceptibility and emission testing of IC's", Proceedings EMCcompo 2007

[6] IEC 61967-8 ed.1, Integrated Circuits – measurements of electromagnetic emissions – part 8: measurement of radiated emissinons – IC stripline method

[7] IEC 62132-8 ed.1, Integrated Circuits – measurements of electromagnetic immunity – part 8: measurement of radiated immunity – IC stripline method

[8] Agilent Technologies, Agilent EMPro, available from: http://www.home.agilent.com/